GRAZING OF *ZEACUMANTUS SUBCARINATUS* (GASTROPODA) ON *ULVA LACTUCA*

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ABSTRACT

Examination of the faeces of *Zeacumantus subcarinatus* shows that macroalgae and associated microflora form a major part of the diet. Dental formula of the radula is 2:1:R:1:2. Examination of grazed fronds of *Ulva lactuca* shows physical damage probably caused by the central and lateral teeth rather than the entire radula.

INTRODUCTION

Zeacumantus subcarinatus (Sowerby) is a small prosobranch gastropod common throughout New Zealand and the Chatham Islands (Suter 1913) on intertidal mudflats and rocky shores (Powell 1976). At Keans Point, Kaikoura, it is found frequently on a range of algae including *Corallina officinalis*, *Colpomenia sinuosa*, *Bostrychia arbuscula*, *Ulva* sp. and *Enteromorpha* sp.. Although *Z. subcarinatus* is reported to be a grazer (Morton and Miller 1968) it is not known whether it feeds primarily on the macroalgae or on the epiphytic microflora. There have been no studies of its diet and no consideration of grazing damage to the algae. The primary aim here is to examine damage to *Ulva lactuca* by the snails' grazing activity, and to relate this to the radula and diet of *Z. subcarinatus*.

METHODS

STUDY AREA AND SAMPLING PROCEDURE

In the Avon-Heathcote estuary, Christchurch, *Z. subcarinatus* is confined to the more saline McCormacks Bay area (Knox and Kilner 1973). A dense population occurs on *U. lactuca*, *Lola litorea*, *Gracilaria secundata* and on the mud surface. Numbers of *Z. subcarinatus* in relation to algal biomass were estimated from 24 randomly placed quadrats (0.022 m^2) in south-west McCormacks Bay. Total numbers of snails on the seaweed and mud surface were counted. No *Z. subcarinatus* were found beneath the mud surface. Each quadrat was then cleared of algae, *U. lactuca* separated from other algae, and all algae dried at 70°C for 48 h and weighed.

FAECAL CONTENTS

Z. subcarinatus found on *U. lactuca* and *L. litorea* in McCormacks Bay were placed in filtered seawater in the laboratory and their faeces collected. Fifty to one hundred faecal pellets of snails from each alga were fragmented in an ultrasonicator for five minutes and filtered onto 0.45 μm HA millipore filters. Air dried filters were mounted on slides in lactophenol-PVA to clear the filter background, and stained for cellulose with Lignin Pink. For snail faeces from each alga twenty-five fields at 400x were examined and faecal contents scored by percentage cover in each field.

SCANNING ELECTRON MICROSCOPE (SEM) EXAMINATION OF *ULVA LACTUCA*

Fronds of *U. lactuca* free from gross visible damage were collected from an area of McCormacks Bay with a low density of grazing animals. Ten 15 mm diameter discs of the alga were cut and placed with 20 snails for grazing for five days in the laboratory (about 2.5x density of snails in field). Algal discs were then fixed in 6% glutaraldehyde in seawater, transferred to seawater and then taken through a series of dilutions to distilled water. This was followed by gradual dehydration of the tissues with acetone in steps of 5, 10, 15, 25, 50, 75, 85, 90, 95, and 100% acetone. Preparation was completed by critical-point drying with CO_2 to minimize surface tension distortion. Mounted specimens were plated with a 50nm layer of vapourized gold in a Polaron E5000 specimen coating unit and stored in a desiccator prior to viewing on a Cambridge Stereoscan 600.

SEM RADULA PREPARATIONS

Radulae were removed from seven snails ⩾ 5mm shell length (from the siphonal notch to the spire apex) and attached tissue dissolved in 10% KOH at 70°C. Each radula was immersed in 70% ethanol and cleaned in an ultrasonicator for 15 s, transferred to a glass sliver immersed in 96% ethanol, and flattened with a weighted cover slip. When the ethanol evaporated, the cover slip was removed and the radula on its glass sliver mounted. A line of high conductivity paint from the glass sliver to the metal stub prevented charging of the specimen (Breure and Ploeger 1977). Before viewing, specimens were coated to increase the resolution at the non-conducting surface of the radula (Hearle *et al.* 1972).

RESULTS

FIELD DATA

The density of *Z. subcarinatus* in McCormacks Bay is very high: Knox and Kilner (1973) reported up to 18,000 m^{-2} from some areas. In this study a mean density of 15,730 m^{-2} was calculated for February, 1979 (Table 1). Mean dry weights for total algae and for *U. lactuca* alone were determined (Table 1). *Ulva lactuca* constituted 62% of algal biomass at that time, but it must be emphasized that this varies seasonally and spatially within McCormacks Bay (Knox and Kilner 1973). Mean numbers of *Z. subcarinatus* per g dry weight of algae in the study area for February, 1979 are shown in Table 1.

TABLE 1. DENSITY OF *Z. SUBCARINATUS* AND STANDING CROP OF ALGAE IN McCORMACKS BAY, FEBRUARY 1979.

	nos m^{-2}	nos g^{-1} alga	dry wt algae (gm^{-2})
Snails > 5 mm	6 630 ± 1 090	49 ± 17	
Snails < 5 mm	9 085 ± 1 290		
Total snails	15 730 ± 2 130	117 ± 28	
U. lactuca			83.0 ± 40.0
Total algae			134.0 ± 21.0

FAECAL CONTENTS

There was little difference in the composition of faeces collected in the laboratory from *Z. subcarinatus* found on *U. lactuca* and *L. litorea* in the field (Fig. 1A, B). The major faecal component (80-90%) was the remains of macro-algal cells, primarily cell wall material (A in Fig. 1A, B). Ten to 20% of faeces consisted of granular, amorphous detritus (B, Fig. 1A, B), whereas diatoms and other material, including marginal teeth of the radula and occasional pollen grains, comprised about 10% (C and D). The similarity between the faeces of snails taken from *U. lactuca* and *L. litorea* may be due to snails in the field feeding on more than one algal species in close succession. The high proportion of cell wall material in the faeces shows that *Z. subcarinatus* causes surface damage to the algae.

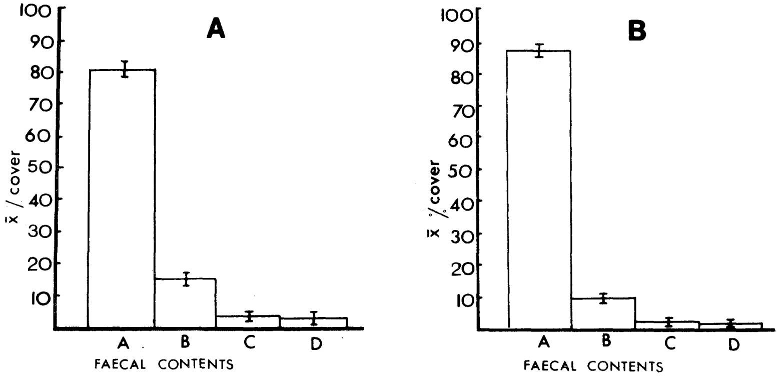

Fig. 1 Faecal contents of *Z. subcarinatus* grazing on *U. lactuca* (A) and on *L. litorea* (B). A = cell wall debris, B = amorphous detritus, C = diatoms, D = other, vertical bar = ± 2SE.

Although the use of faecal contents as an index of diet is open to bias due to differential digestion of foods, and because there may be bacterial contamination from endemic gut flora and other sources (Calow 1973, 1974), this study is concerned only with identification of resistant cell walls, diatom frustules and detritus. It is recognized that epiphytic bacteria and blue-green algae may form part of the diet also.

RADULA STRUCTURE

The radula formula for *Z. subcarinatus* is 2:1:R:1:2 (Fig. 2D). Each transverse row bears a median tricuspid rachidian tooth (R), bearing distally a large central and two smaller lateral, posteriorly-directed cusps, and two posterior proximal cusps (Fig. 2E). On either side, a single lateral tooth bears five small and two larger cusps, angled inwards towards the rachidian tooth (Fig. 2D, L). The two marginal teeth (M) are equal in size but differ in that the innermost has five rather than six cusps.

Loss of teeth from the more anterior end of the radula may occur during feeding; Runham and Thornton (1967) found almost one quarter of the small marginal teeth at the anterior end of the radula of *Patella vulgata* were completely missing. The presence of marginal teeth in the faeces of *Z. subcarinatus* suggests that tooth loss also occurs in this species.

SURFACE DAMAGE TO *U. LACTUCA* FRONDS

SEM examination of the surfaces of the fronds revealed an epiphytic carpet composed primarily of bacteria with scattered diatoms and blue green algae. Fronds used in the grazing experiments had a mean bacterial cell density of 5.8-8.2 x $10^6 cm^{-2}$ (McClatchie, unpublished data) although densities probably vary seasonally and with growth of the seaweed (Sieburth *et al.* 1974).

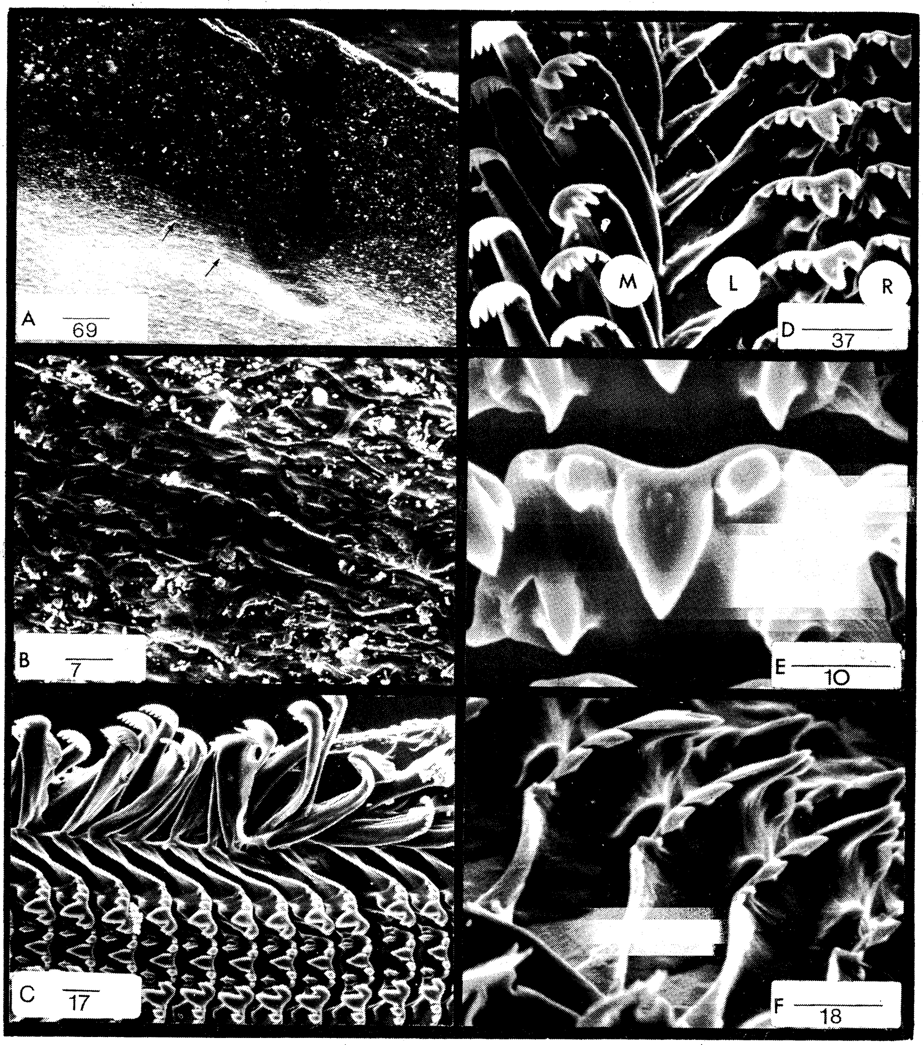

Fig. 2 A, surface scrape on *U. lactuca*; B, close-up of scrape. *Z. subcarinatus* radula; C, rachidian, lateral and marginal (one side) teeth; D, detail of lateral (L) and marginal (M) teeth; E, rachidian tooth; F, lateral teeth, oblique view. Scale in µm.

Scraped areas, apparently caused by the radula of *Z. subcarinatus* were found on the fronds grazed in the laboratory (Fig. 2A). Distinct lines of gouging are visible in Fig. 2B. The scrapes remove outer cell walls along with epiphytic bacteria and diatoms. Control samples of the same fronds fixed immediately after collection showed no evidence of surface scraping.

Mean scrape width was determined by measuring seven scrapes on the experimentally grazed fronds and compared with the mean radula width (n = 5) of snails from the grazing experiment (Table 2). The mean width of scrapes is considerably narrower than the mean radula width. If the mean width of the central tooth and the single lateral tooth to either side of it (0.204mm) is compared with the mean scrape width (0.105mm) there is still a large discrepancy. However, if only the areas of these three teeth that bear cusps are considered (mean width = 0.072mm) (Fig. 2C), the correspondence is much closer. The narrowness of the scrapes indicates that they have been made by a relatively shallow penetration of the cusps of the rachidian and lateral teeth.

TABLE 2. *Z. SUBCARINATUS* RADULA WIDTH AND WIDTH OF SCRAPES ON *U. LACTUCA* FRONDS.

	Scrape width (mm)	Width of central and lateral teeth cusps (mm)	Width of central and lateral teeth (mm)	Radula width (mm)
$\bar{x}$	0.105	0.072	0.204	0.354
2SE	0.05	0.004	0.038	0.047
n	7	5	6	6

DISCUSSION

Although thalli of *U. lactuca* had a rich bacterial epiflora with scattered pennate diatoms and blue-green algae, larger multicellular epiphytes that could provide food for *Z. subcarinatus* were not found. The high proportion of cellular debris in *Z. subcarinatus* faeces suggests that it damages plants upon which it grazes and the discovery of scraped areas on *U. lactuca* fronds confirms this. No scrapes were found on ungrazed fronds. The close agreement between mean scrape width and width of the cusped areas of the rachidian and lateral teeth strongly suggests that they were caused by *Z. subcarinatus*.

Among grazers, food selection and its availability are closely related to the capacity of the grazers to overcome the plants' physical or chemical defence mechanisms (Calow 1973). The primary barrier encountered by grazers feeding on *U. lactuca* is its cellulose cell wall. Although chemically resistant cuticles are known for 11 species of chlorophycean marine algae, there is no evidence that the cell walls of *U. lactuca* possess a proteinaceous layer similar to that of *Chaetomorpha* (Hanic and Craigie 1969) which might prove more resistant to rasping. SEM evidence presented here suggests that *Z. subcarinatus* is capable of inflicting significant damage to cell walls of *U. lactuca*.

The primary food of *Z. subcarinatus* may be the rich microflora growing on the surface of the fronds, damage to *U. lactuca* being incidental. Whatever the primary source of nutrition to the animal, damage to the *U. lactuca* fronds is considerable. Grazing will also affect the biomass of the epiphytic microbial flora by removing part of the population and possibly providing nutrient enrichment derived from damaged macro-algal cells for re-colonizing bacteria. Further study has examined the effect of *Z. subcarinatus* grazing on the microbial epiflora.

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